

Nanoscale Magnetism at The University of Alabama

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The University of Alabama Proposes to be the **Nanomagnetism Southeast** Node on the National Nanotechnology Infrastructure Network

The Center for Materials for Information Technology at the University of Alabama has

- a NSF MRSEC in Materials for Magnetic Data Storage and Molecular Recording
- a broad suite of magnetic characterization equipment
- multi-scale computational modeling of magnetic nanostructures
- graduate education in a multidisciplinary team environment
- outreach to HBCU faculty
- technology transfer to industry

Center for Materials for Information Technology

A NSF Materials Research Science and Engineering
Center

Basic research in the materials science underpinning
future data storage devices

Two IRG's

IRG-1 Magnetic Storage

Materials science for heads and media for future
magnetic data storage devices with capacities
beyond 1 terabit per square inch

IRG-2 Molecular Storage

Materials science in probe-based storage in self-
assembled films consisting of redox gradient
dendrimers with potential data storage densities
beyond 100 terabits per square inch

Faculty in the Center for Materials for Information Technology

Twenty-two faculty from six departments in two different colleges
Includes

two fellows of the American Physical Society,
one Fellow of the American Ceramics Society,
two IEEE Fellows,
one IEEE Magnetics Society Achievement award winner
and two NSF CAREER grantees.

Chester Alexander, Jr., Physics, Magnetization
Dynamics;

Martin Bakker, Chemistry, Self-assembly and
Templating of Magnetic Nanostructures;

Silas Blackstock, Chemistry, Molecular Data Storage
Materials;

William H. Butler, Physics, Theory of Magnetism and
Magnetotransport

William D. Doyle, Physics, Magnetic Materials and
Devices;

Hideo Fujiwara,, Physics (Adjunct), Magnetic Thin
Films; GMR/Spin Valves;

J.W. Harrell, Jr., Physics, Magnetic Media
Characterization;

Duane Johnson, Chemical Engineering, Fluid
Dynamics;

Lowell D. Kispert, Chemistry, EPR and ENDOR
Spectroscopy;

Tonya M. Klein, Chemical Engineering, Chemical
Vapor Deposition;

Gary Mankey, Physics, Ferro and Anti-Ferromagnetic
Interfaces;

Robert M. Metzger, Chemistry, Molecular Electronics;

David E. Nikles, Chemistry, Magnetic and Optical
Media Chemistry;

R. Kumar Pandey, Electrical Engineering, Application
of Magnetic Oxide Materials

Rainer Schad, Physics, Magnetic Films and Interfaces;
Spin Tunneling Structures;

Min Sun, Applied Mathematics, Modeling, Analysis
and Optimal Control of Physical Systems;

Shane Street, Chemistry, Surface Science and Tribo-
Chemistry;

Greg Szulczewski, Chemistry, Molecular Data Storage;

Pieter Visscher, Physics, Computer Simulation of
Particulate Systems;

Garry W. Warren, Metallurgical & Materials
Engineering Corrosion, Electrochemistry, Metal-
Polymer Interfaces;

Mark Weaver, Metallurgical & Materials Engineering
Tribology, Microstructural Characterization;

John Wiest, Chemical Engineering., Non-Newtonian
Fluid Mechanics and Tape Coating Processes

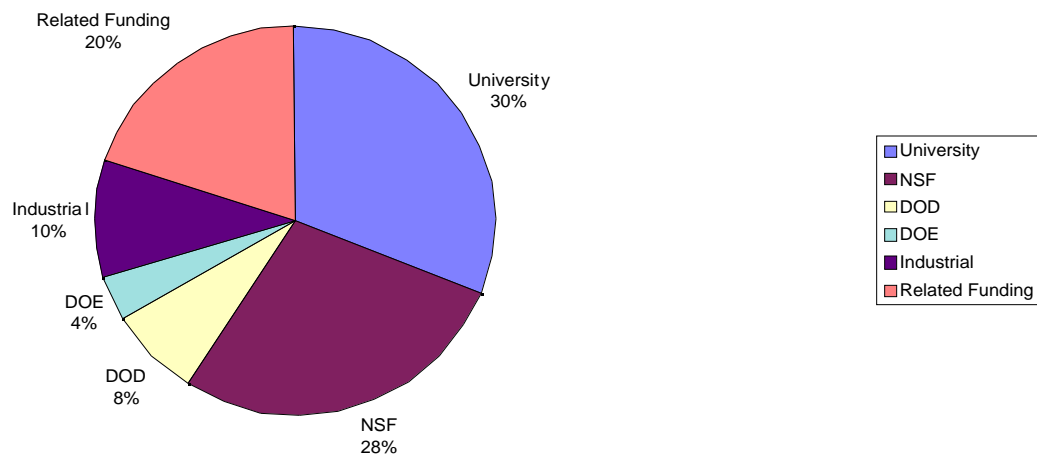
THE UNIVERSITY OF ALABAMA

Center for Materials for Information Technology

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Center Budget

Center Funding for 2002 - 2003 Total \$3.9M



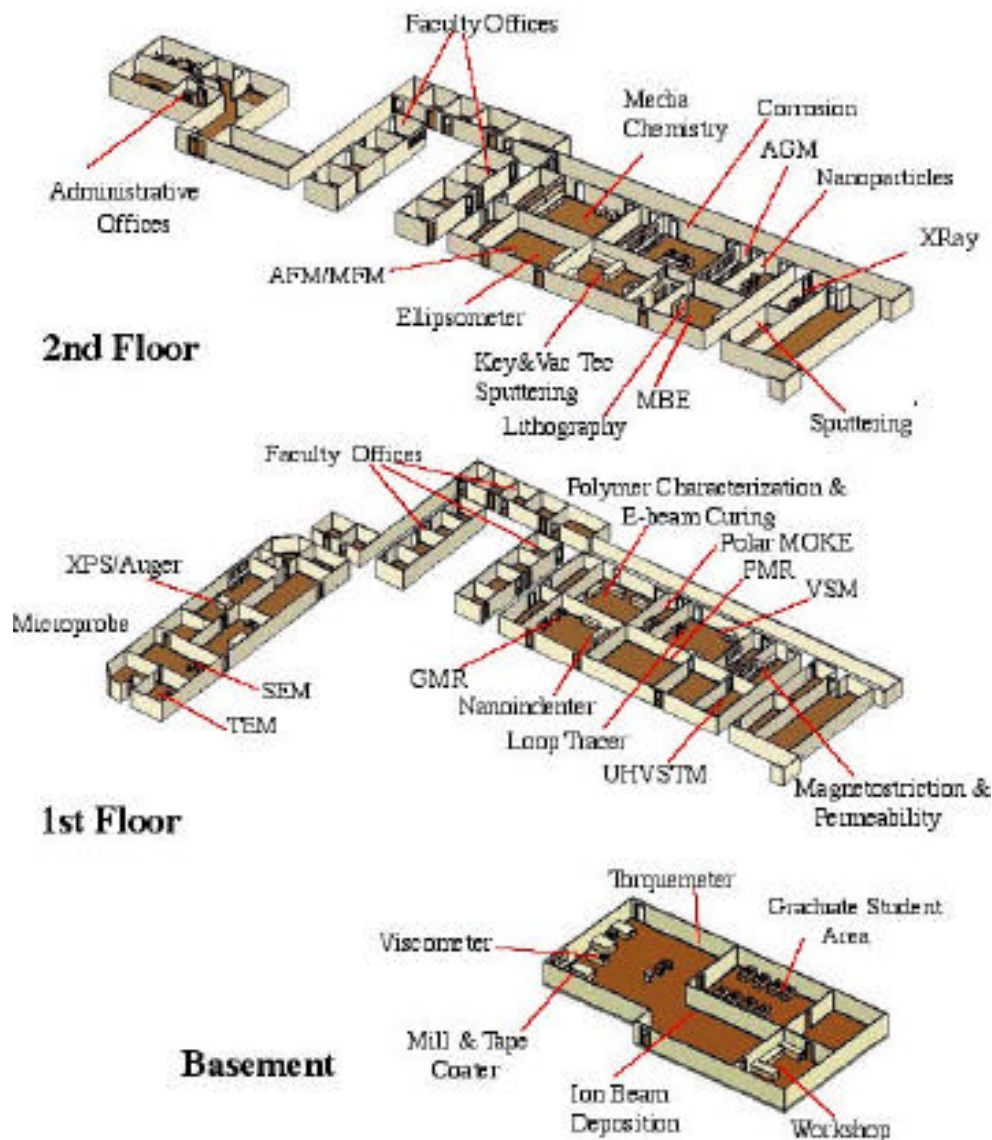
Major Funding Sources

NSF MRSEC

Individual Investigator Awards

Corporate Sponsors

Shared User Facilities



Our Center is located on three floors on the Bevill Building

The faculty share the space and facilities

There are two clean rooms

Professional staff (Ph. D. level) manages the facilities

Students are trained on the use of equipment and are then allowed hand-on access for their dissertation research

THE UNIVERISTY OF ALABAMA

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Magnetic Characterization Capabilities

Magnetometry

- Digital Measurements Vibrating Sample/Torque Magnetometer (15 kOe, 100 K – 600 K)
- Oxford MagLab VSM (0 – 9 T, 1.5 K – 1000 K)
- Alternating gradient magnetometer (0 – 20 kOe, 10 K – 600 K)
- Magneto-optical Kerr effect (MOKE)

Magnetotransport

- We have 2-probe and 4-probe magnetotransport measurement setups.

Temperature 7 to 350 K and magnetic fields up to 2 T

- The new Oxford VSM will be equipped with a transport sample holder which will allow measurements in the temperature range 1.5 K to 900 K in magnetic fields up to 9 T.
- AC and DC transport measurements over a wide range of impedances. A specialized setup is currently under construction to allow noise power measurements in the frequency range 10mHz to 10kHz in a shielded environment with fields up to 100 Oe and temperatures from 200 K to 350 K.

Probe Microscopy

- Digital Instruments AFM/MFM

Magnetic Characterization Capabilities

High-Frequency Permeability Measurements

- Measurements can be made on films at frequencies up to 6 GHz
- Data can be used to determine the damping constant, α , and the resonance frequency, f , of the film as a function of applied magnetic field

FMR Spectroscopy

- The facilities for EPR/FMR are unsurpassed in this country, with four frequencies available;
 - 9 GHz (X-band, 0.3 T),
 - 15 GHz, 24 GHz (K-band, 0.9 T),
 - 33 GHz (Q-band, 1.2 T)
 - 95 GHz (W-band, 3 T)
- Characterize the anisotropy
- Calculate values of the damping constant from the line-width

High-Speed Pulse Magnetometry

- Subject a magnetic sample to nanosecond magnetic field pulses
- Measure magnetic remanence

Multi-scale Magnetic Modeling

Atomic Scale

- First principles based modeling of electronic and magnetic structure using state of the art electronic structure codes.
- First-principles based calculations of transport using a suite of codes that can treat electron transport at several levels of approximations from fully quantum-mechanical through semi-classical.

Mesoscale

- UA group has developed general and efficient codes for micromagnetic simulation (soft films, hard perpendicular media, MRAM elements, current-driven switching, self-assembled arrays)
- Animated visualization capability is built in; group has developed several innovative visualization methods

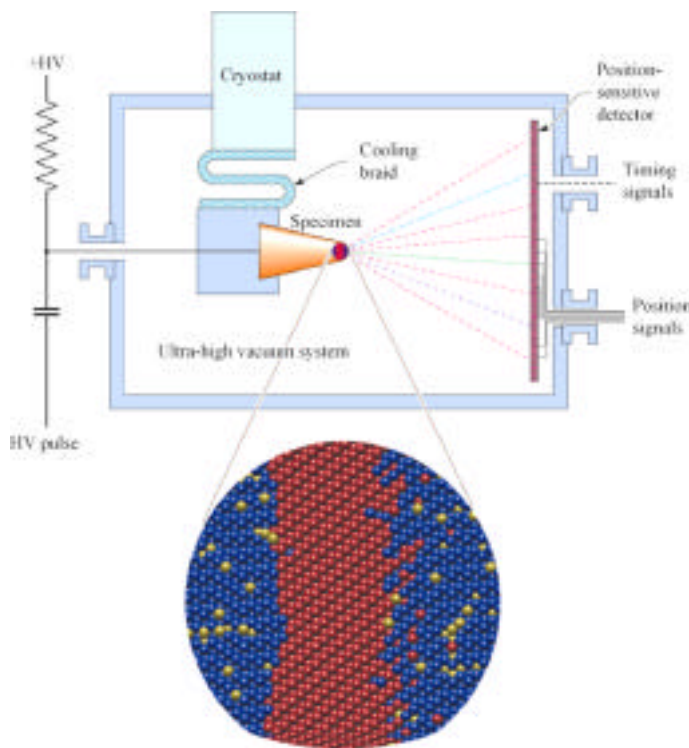
Bridging the scales

- Research within our MRSEC is directed at marrying the atomic scale and mesoscale codes

Atom Probe

Characterization of Multilayers at the Atomic Scale using Atom Probe Field Ion Microscopy

- Determine the atomic scale structure of multilayers
- Developing this technique for characterizing magnetic samples with nanoscale dimensions
- Collaboration between the University of Alabama (Mark Weaver) and Oak Ridge National Laboratory



Schematic illustration of the 3DAP approach for atomic scale characterization [X. W. Zhou, H. N. G. Wadley, R. A. Johnson, D. J. Larson, N. Tabat, A. Cerezo, A. K. Petford-Long, G. D. W. Smith, P. H. Clifton, R. L. Martens and T. F. Kelly, "Atomic scale structure of sputtered metal multilayers," *Acta Materialia* 49 (2001) 4005-4015].

Education

Graduate Education in a Multidisciplinary Team Environment

Pursue Ph. D.'s in Chemistry, Physics, Chemical Engineering, Metallurgical and Materials Engineering or Materials Science

Students pursue their dissertation research in multidisciplinary teams

The research activities are scrutinized and planned during biweekly team meetings

Consensus management with every member of the team contributing to project planning — ownership and responsibility to the project goals

Students must commit themselves to complete their research tasks in a timely manner so that other team members can complete their own tasks

More than half of our M. S. and Ph. D. graduates and former post docs have found rewarding employment in the high tech information storage industry



David Arrington (chemistry doctoral candidate) presents his research results at a multidisciplinary team meeting

Research Experiences for Undergraduates

Provide a summer research experience in materials science for undergraduate science and engineering majors

Outreach to women and minorities

Interest undergraduate science and engineering majors in careers in information technology

“The Extreme Sport of Physics”

M. Kryder



Collaborative & Interdisciplinary Research
Jonathan Brauer (2000 REU) participates in group research meeting with Profs. Szulczewski and Blackstock and graduate students K. Kim and Trent Selby



Hands-on experience with state of the art equipment
Jakeithia Prejean (1999 REU) measures resistivities of sputtered thin films.

THE UNIVERSITY OF ALABAMA

Center for Materials for Information Technology

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Outreach to HBCU Faculty

NSF-sponsored three-week summer workshop

“Introducing Science Faculty from Historically Black Colleges and Universities to Materials Science and Engineering”

Administered by Professors Viola Acoff and Mark Weaver

MRSEC faculty assist by giving lectures and providing laboratory demonstrations

Web page: <http://bama.ua.edu/~ua-mse/content.html>



2001 HCU Workshop Participants

Research Experiences for HBCU Faculty

Objectives

To develop long-term research collaborations between the MRSEC and faculty at HBCUs

Provide opportunities for minority students to participate in materials science research

Approach

Each summer two HBCU faculty (from the workshop) are selected to spend the remainder of the summer doing research with a MRSEC team.

If the faculty can also bring a student, that student will participate in our REU program

Establish on-going research collaborations beyond the summer

Research Experiences for HBCU Faculty



Summer 2002

Professor Justin Akujieze (Chicago State University, 2nd from right) and Kara Scott (also from Chicago State U., middle) conduct research in our clean room with Gary Mankey (3rd from right) and his group

Outreach to Industry

Transfer of knowledge to the information storage industry

Education of scientists and engineers

Publications and presentations

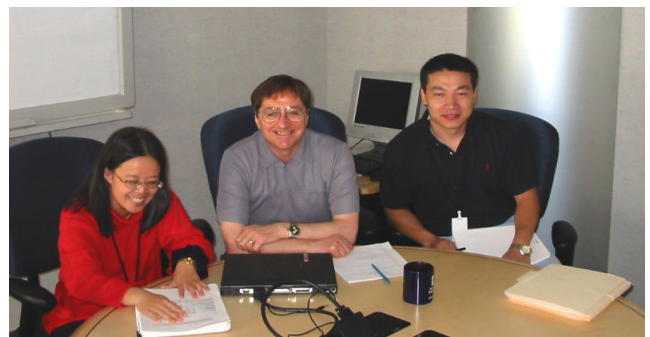
Interaction with the corporate sponsors of MINT

Participation in the International Storage Industry Consortium (INSIC)

Workshops

Reviews for our Corporate Sponsors

Visit to Seagate's Pittsburgh Technology Center 6/21/02



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The University of Alabama and the National Nanotechnology Infrastructure Network

Nanomagnetism Southeast

Broad suite of magnetic characterization tools

Computational tools for magnetism

Graduate education in a multidisciplinary team environment

Outreach to HBCU faculty

Technology transfer to industry

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